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(54) WHEEL LOADER

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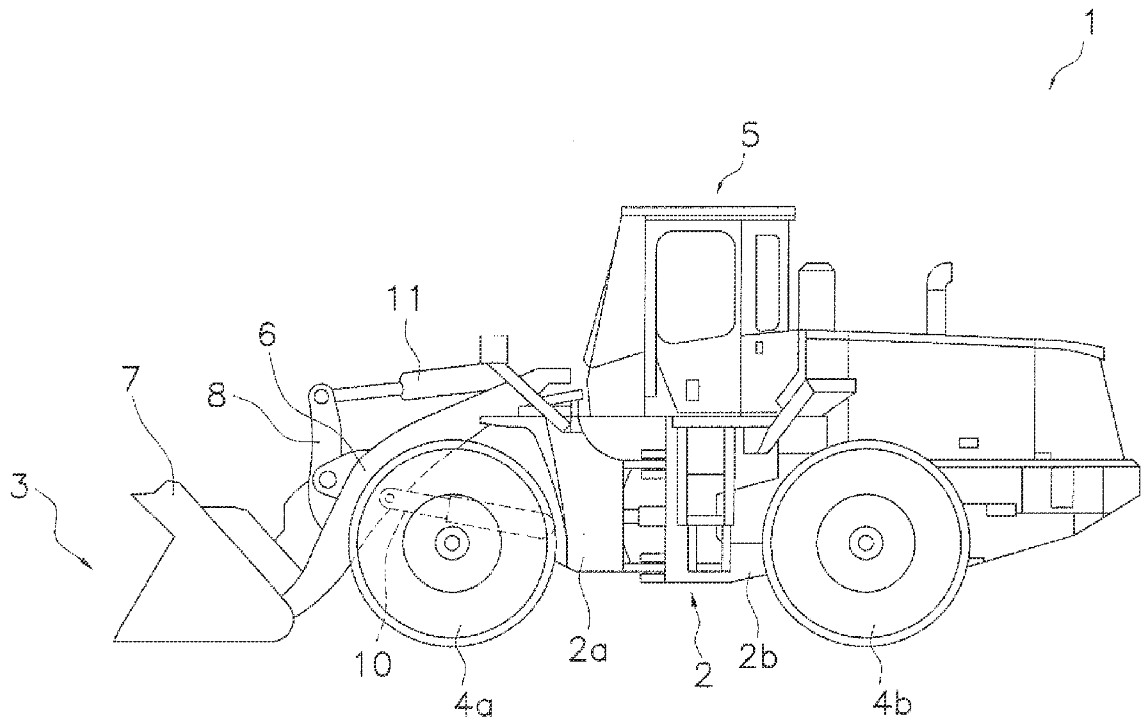
(52) **U.S. Cl.** **701/50**

(57) **ABSTRACT**

An engine control device of the wheel loader includes a travelling state detecting unit for detecting a travelling state of the wheel loader, a mode switching determining unit, an acceleration speed detecting unit and a switching time controlling unit. The acceleration speed detecting unit detects the acceleration speed of the wheel loader when the mode switching determining unit determines that it is required to switch between the engine output modes from a tow output mode to a high output mode based on a detection result of the travelling state detecting unit. The switching time control unit controls the switching time from start to end of mode switching to he: a first time when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and a second time greater than the first time when the detected acceleration speed is positive.



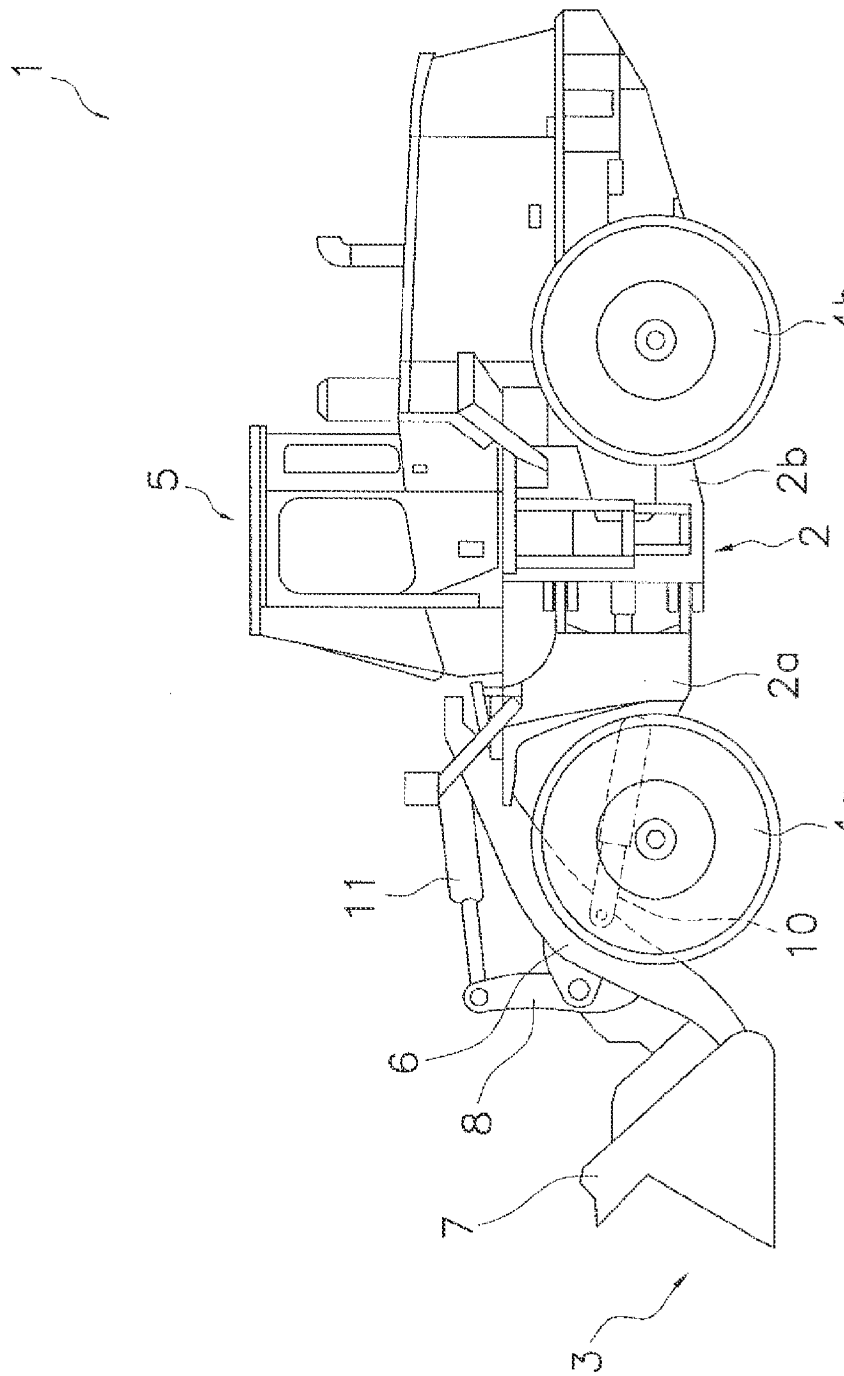
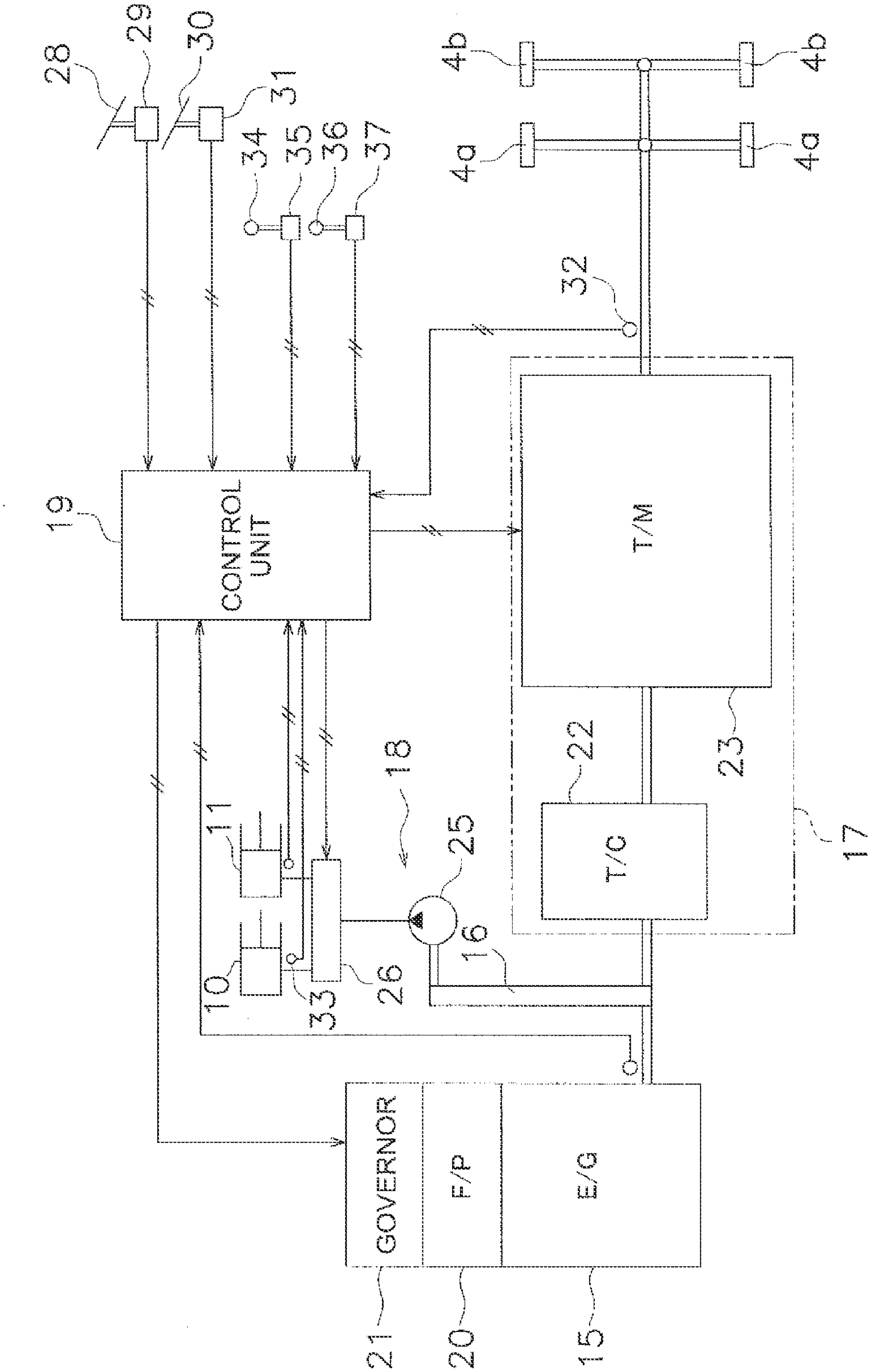


FIG. 1



CONTROL UNIT
T/M
T/C
GOVERNOR
F/P
E/G
4a
4b
10
11
15
16
17
18
19
20
21
22
23
25
26
28
29
30
31
32
33
34
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36
37

FIG. 2

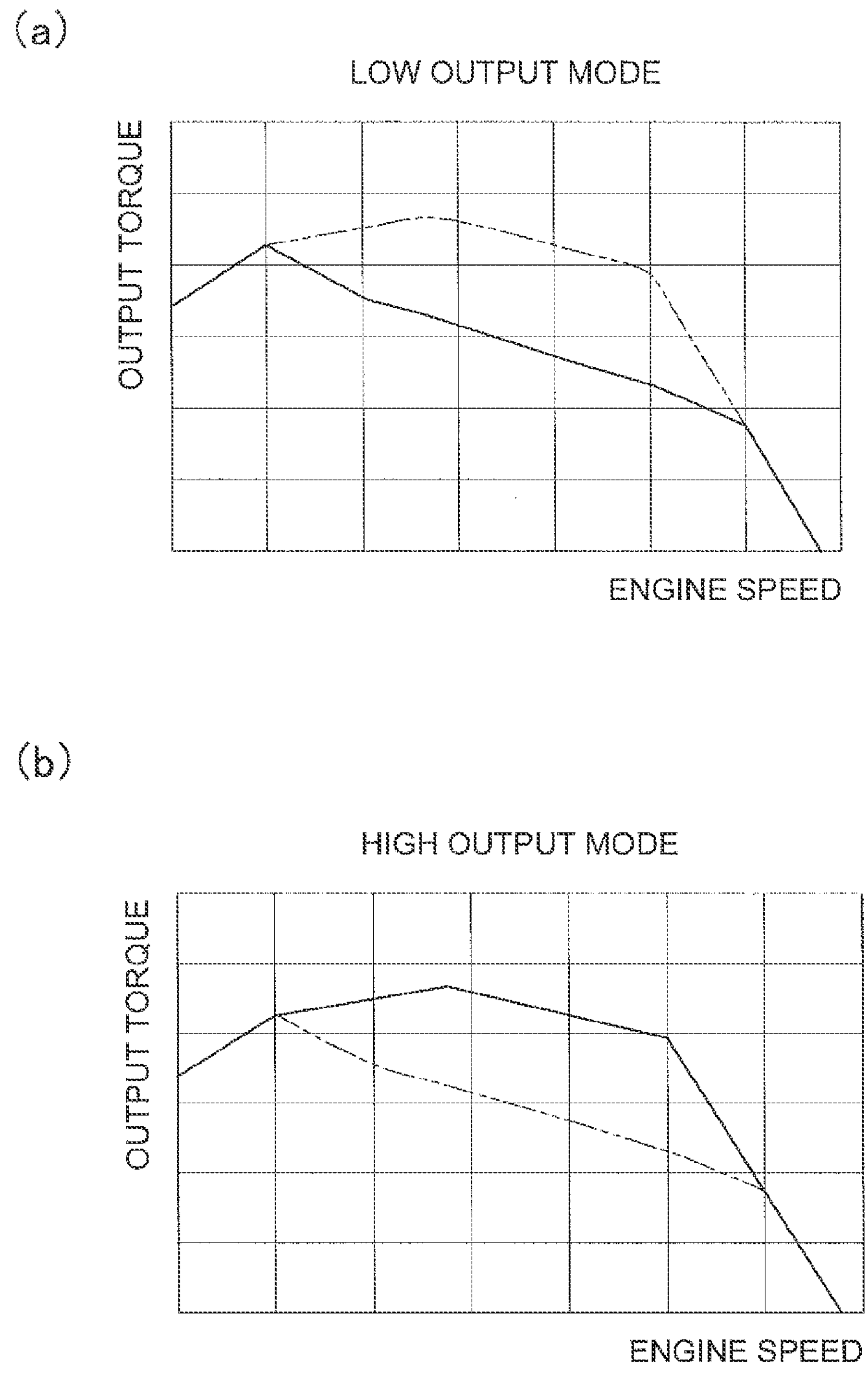
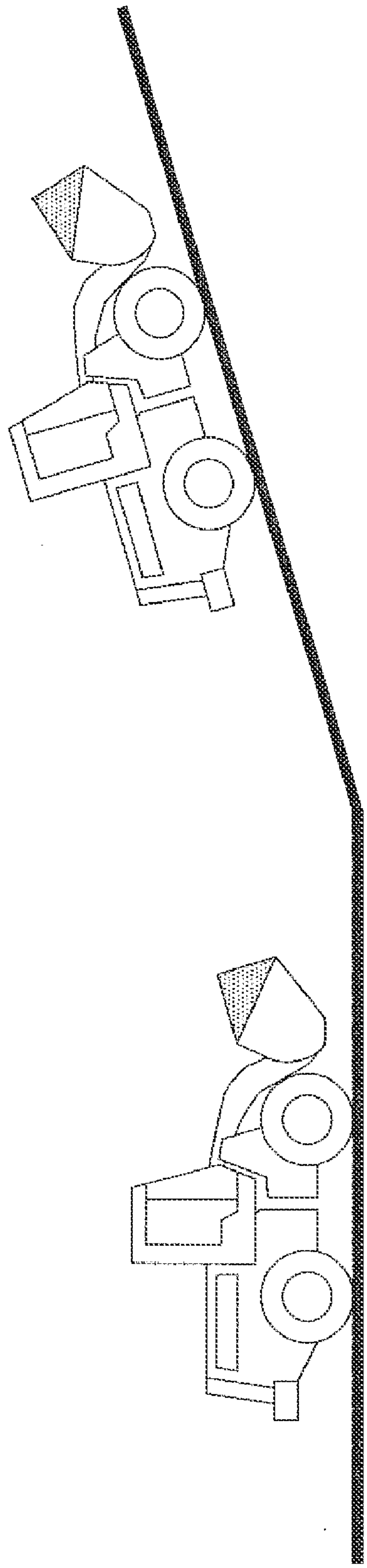

(a)
LOW OUTPUT MODE
OUTPUT TORQUE
ENGINE SPEED
(b)
HIGH OUTPUT MODE
OUTPUT TORQUE
ENGINE SPEED

FIG. 3



(a)

(b)

FIG. 4

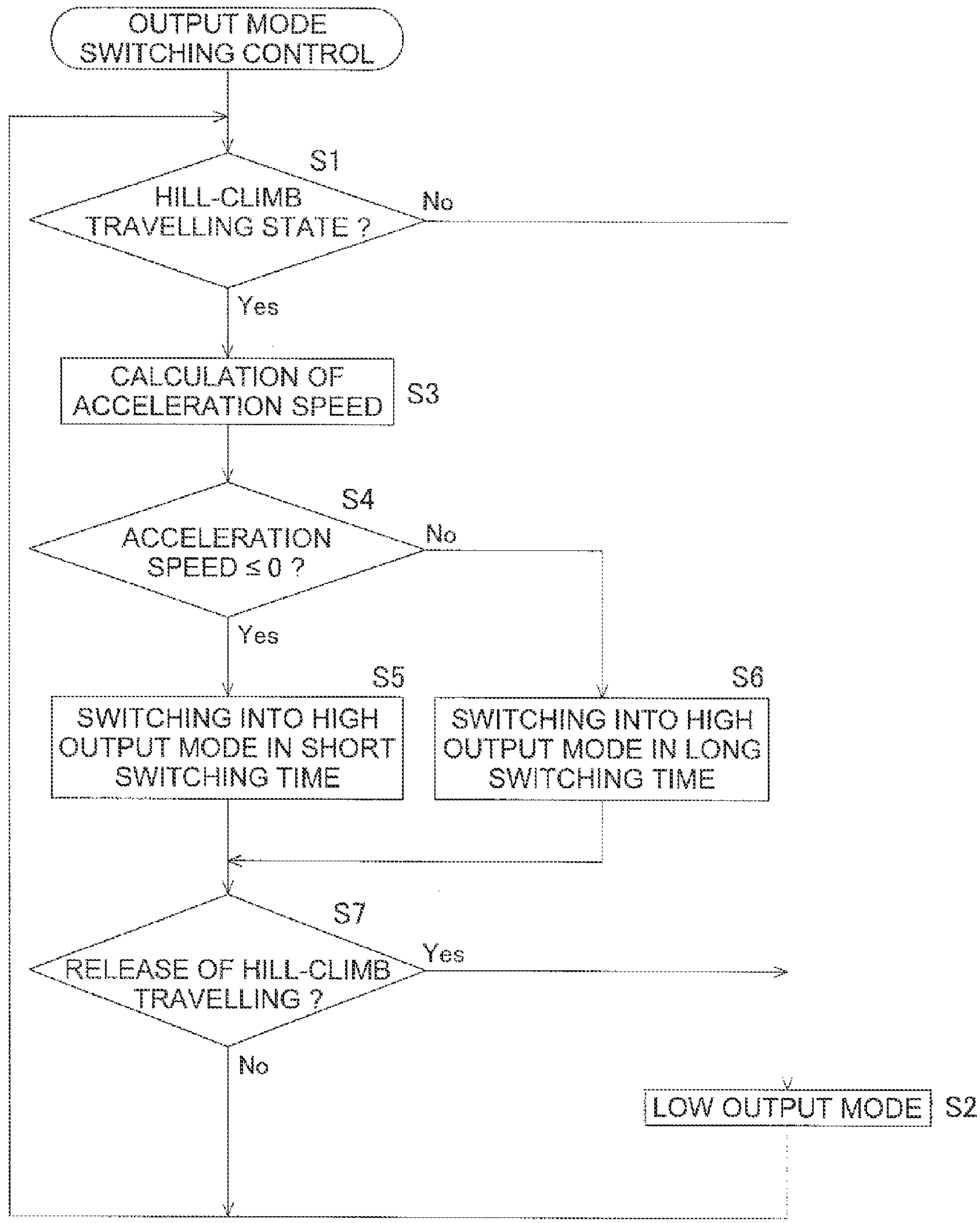

OUTPUT MODE SWITCHING CONTROL
S1
HILL-CLIMB TRAVELLING STATE ?
No
Yes
CALCULATION OF ACCELERATION SPEED
S3
S4
ACCELERATION SPEED ≤ 0 ?
No
Yes
S5
SWITCHING INTO HIGH OUTPUT MODE IN SHORT SWITCHING TIME
S6
SWITCHING INTO HIGH OUTPUT MODE IN LONG SWITCHING TIME
S7
RELEASE OF HILL-CLIMB TRAVELLING ?
Yes
No
LOW OUTPUT MODE
S2

FIG. 5

FIG. 6

VEHICLE SPEED
(OUTPUT SHAFT ROTATION SPEED)

(rpm)

1ST SPEED	2ND SPEED	3RD SPEED	4TH SPEED
800	1300	2300	3000

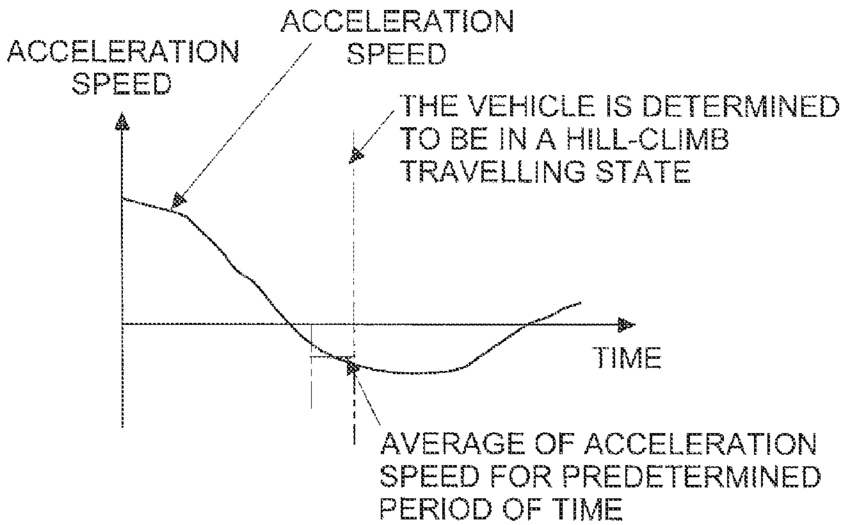
FIG. 7

ACCELERATION SPEED
(CHANGE RATE OF OUTPUT SHAFT ROTATION SPEED)

(rpm/sec)

1ST SPEED	2ND SPEED	3RD SPEED	4TH SPEED
100	80	70	60

FIG. 8



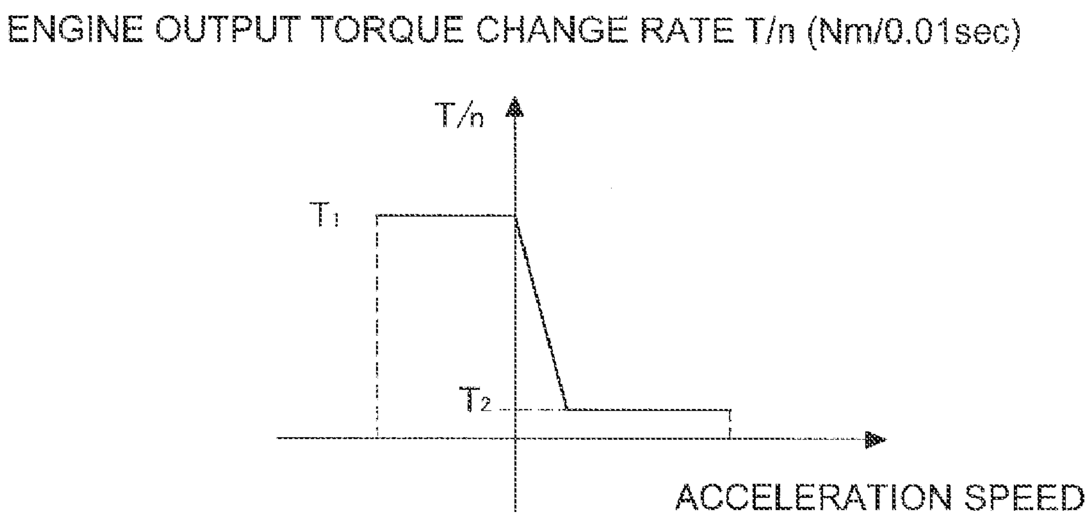
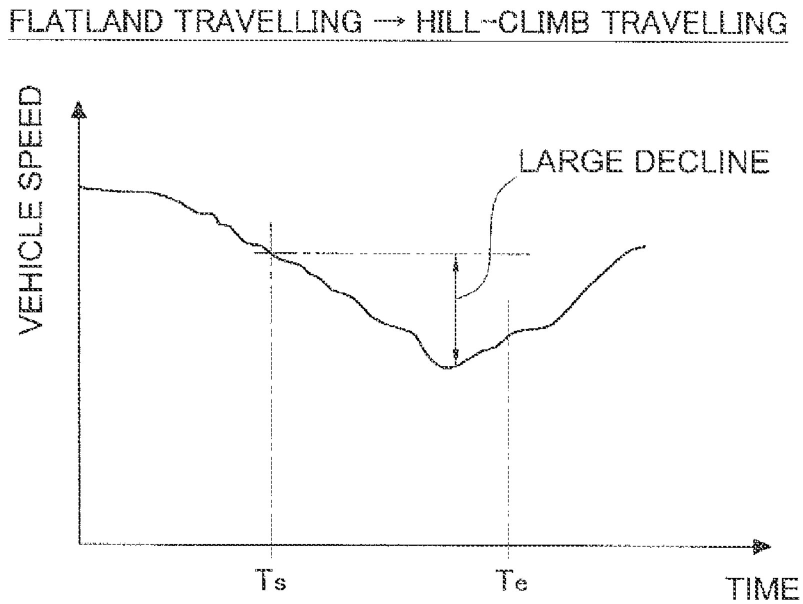

ENGINE OUTPUT TORQUE CHANGE RATE T/n (Nm/0.01sec)
T/n
T1
T2
ACCELERATION SPEED

FIG. 9

(a)


FLATLAND TRAVELLING → HILL-CLIMB TRAVELLING
VEHICLE SPEED
LARGE DECLINE
Ts
Te
TIME

(b)

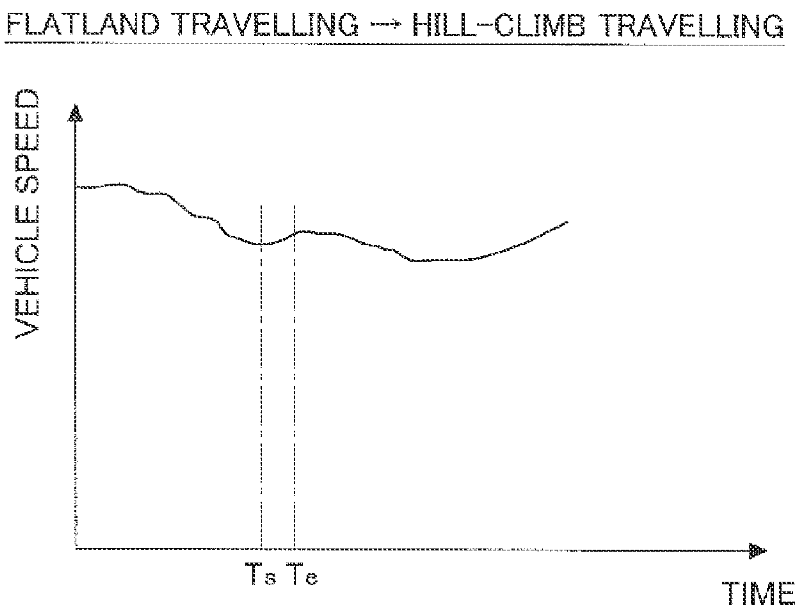
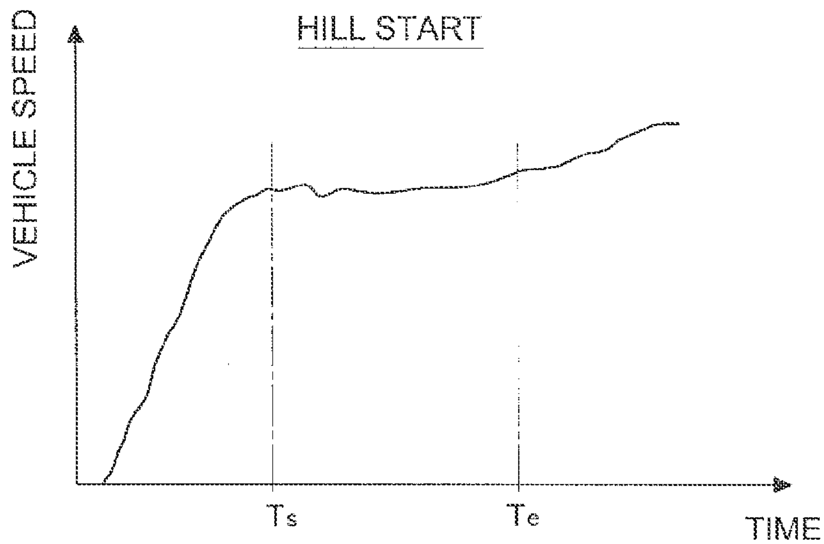

FLATLAND TRAVELLING → HILL-CLIMB TRAVELLING
VEHICLE SPEED
Ts Te
TIME

FIG. 10

(a)


HILL START
VEHICLE SPEED
Ts
Te
TIME

(b)

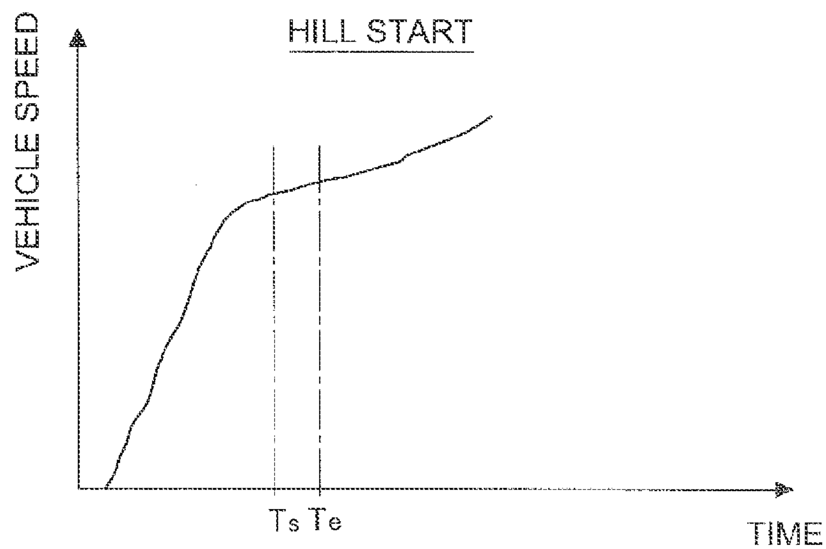

HILL START
VEHICLE SPEED
Ts
Te
TIME

FIG. 11

WHEEL LOADER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Japanese Patent Application No. 2010-288263 filed on Dec. 24, 2010, the disclosure of which is hereby incorporated herein by reference in its entirety

TECHNICAL FIELD

[0002] The present invention relates to a wheel loader including an engine control device configured to execute a control of switching between engine output modes from a low output mode to a high output mode or vice versa.

BACKGROUND ART

[0003] As described in International Patent Application Publication No. W02005/024208 A1 and etc., a low output mode for allowing an engine to exert low output performance and a high output mode for allowing the engine to exert high output performance are set as engine output modes in work vehicles such as wheel loaders. Further, in the case of flatland travelling, for instance, light load acts on the en e, and therefore, the low output mode is selected for reducing fuel consumption. In the case of hill-climb travelling, by contrast, the high output mode is selected because a high output is required. Switching controls from the low output mode to the high output mode and vice versa are configured to be automatically executed depending on load and etc.

SUMMARY

[0004] The following drawbacks are caused in the work vehicle described in Patent Literature 1 when the low output mode is switched into the high output mode especially in hill-climb travelling.

[0005] First, explanation will be made for the case that the work vehicle shills from flatland travelling to hill-climb travelling. While the work vehicle travels on a flatland, a light load acts on the engine and therefore the low output mode is selected as an output mode as described above. When it is then detected that the work vehicle has shifted to hill-climb travelling, the low output mode is switched into the high output mode. When switching timing is delayed in such a phase, the vehicle speed is reduced and acceleration performance is also degraded in the initial stage after the work vehicle shifts to hill-climb travelling. Therefore, it is required to quickly switch the low output mode into the high output mode.

[0006] When the work vehicle is started moving from halfway up a hill, an operation of the work vehicle is started in the low output mode similarly to when the work vehicle is started moving on a flatland. When it is then detected that the work vehicle is started moving on a hill through the detection by an inclination sensor, load detection and etc., the low output mode is switched into the high output mode. When the output mode is quickly switched in such a phase similarly to the above, engine output performance is increased although engine load is unchanged. Therefore, the vehicle is supposed to be abruptly accelerated. This makes an operator feel strange.

[0007] It is an object of the present invention to execute an appropriate switching control depending on a phase in switching between engine output modes in a wheel loader for achieving smooth travelling and simultaneously for preventing an operator from having a feeling of strangeness.

[0008] A wheel loader according to the first aspect of the present invention is a wheel loader having a low output mode and a high output mode as engine output modes. The wheel loader includes an engine, a driving wheel, a power transmission device, a work implement and an engine control device. The power transmission device is configured to transmit driving force from the engine to the driving wheel. The work implement is configured to be driven by the driving force from the engine. The engine control device is configured to execute a control of switching between the engine output modes from the low output mode to the high output mode or vice versa. The engine control device includes a travelling state detecting unit, a mode switching determining unit, an acceleration speed detecting unit and a switching time controlling unit. The travelling state detecting unit is configured to detect a travelling state of a vehicle (wheel loader). The mode switching determining unit is configured to determine based on a detection result by the travelling state detecting unit whether or not it is required to switch between the engine output modes from the low output mode to the high output mode. The acceleration speed detecting unit is configured to detect an acceleration speed of the vehicle when the mode switching determining unit determines that it is required to switch between the engine output modes. The switching time controlling unit is configured to control a switching time from start to end of the mode switching to be: a first time when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and a second time greater than the first time when the detected acceleration speed is positive. It should be noted that the acceleration speed may be either an acceleration speed in switching between modes or an average of acceleration speeds in an immediate predetermined period of time including a point of time in switching between modes.

[0009] The present engine control device detects a travelling state of the vehicle such as hill-climb travelling or hill start. Based on the detection result, the engine output modes are switched from the low output mode to the high output mode. Further, the acceleration speed of the vehicle is detected in switching between modes, Yet further, a period of time from start to end of switching between the output modes is controlled depending on a detected result of the acceleration speed. Specifically; the switching time is controlled to be the first time when the detected acceleration speed is either 0 or negative. On the other hand, the switching time is controlled to be the second time greater than the first time when the detected acceleration speed is positive.

[0010] For example, when the vehicle has shifted from flatland travelling to hill-climb travelling, the vehicle reduces the vehicle speed. Therefore, the acceleration speed becomes either 0 or negative. In such a case, the switching time is reduced and the engine output modes are quickly switched from the low output mode to the high output mode. Accordingly, it is possible to inhibit a situation that the vehicle speed is reduced and thereby acceleration performance is degraded when the vehicle has shifted to hill-climb travelling.

[0011] On the other hand, the vehicle is accelerated at hill start, although the acceleration is gentle. Therefore, the acceleration speed becomes positive in such a case, the switching time is increased contrary to the aforementioned case. Accordingly, it is possible to avoid a situation that the work vehicle abruptly accelerates immediately after hill start. It is thereby possible to inhibit an operator from having a feeling of strangeness.

[0012] A wheel loader according to a second aspect of the present invention is a wheel loader having a low output mode and a high output mode as engine output modes. The wheel loader includes an engine, a driving wheel, a power transmission device, a work implement and an engine control device. The power transmission device is configured to transmit driving force from the engine to the driving wheel. The work implement is configured to be driven by the driving force from the engine. The engine control device is configured to execute a control of switching between the engine output modes from the low output mode to the high output mode or vice versa. The engine control device includes a travelling state detecting unit, a mode switching determining unit, an acceleration speed detecting unit and an output torque change rate controlling unit. The travelling state detecting unit is configured to detect a travelling state of a vehicle. The mode switching determining unit is configured to determine based on a detection result by the travelling state detecting unit whether or not it is required to switch between the engine output modes from the low output mode to the high output mode. The acceleration speed detecting unit is configured to detect an acceleration speed of the vehicle when the mode switching determining unit determines that it is required to switch between the engine output modes. The output torque change rate controlling unit is configured to control a change rate of an output torque of the engine from start to end of the mode switching to be: a first change rate when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and a second change rate less than the first change rate when the detected acceleration speed is positive. It should be noted that similarly to the above, the acceleration speed may be either an acceleration speed in switching between modes or an average of acceleration speeds in an immediate predetermined period of time including a point of time in switching between modes.

[0013] Similarly to the first aspect of the present invention, the present engine control device switches between the engine output modes from the low output mode to the high output mode based on the detection result of the travelling state of the vehicle, and further, the acceleration speed of the vehicle is detected. Then, the change rate of the engine output torque in switching between modes is controlled in accordance with the detection result of the acceleration speed. Specifically; the change rate of the engine output torque is controlled to be the first change rate when the detected acceleration speed is either 0 or negative while being controlled to be the second change rate less than the first change rate when the detected acceleration speed is positive.

[0014] Even the second aspect of the present invention can achieve an advantageous effect similar to that achieved by the first aspect of the present invention. Specifically, the change rate of the engine output torque is controlled to be the relatively large first change rate when the vehicle has shifted from flatland travelling to hill-climb travelling. Therefore, the mode switching time is reduced and the engine output modes are quickly changed from the low output mode to the high output mode. Accordingly; it is possible to inhibit a situation that the vehicle speed is reduced and acceleration performance is thereby degraded when the vehicle has shifted to hill-climb travelling.

[0015] On the other hand, the change rate of the engine output torque is controlled to be the relatively small second change rate at hill start. Therefore, the mode switching time is increased and it is possible to avoid a situation that the work vehicle abruptly accelerates immediately after hill start. As a result, it is possible to inhibit an operator from having a feeling of strangeness.

[0016] A wheel loader according to a third aspect of the present invention relates to the wheel loader according to one of the first and second aspects of the present invention. In the wheel loader, the travelling state detecting unit is configured to detect that the vehicle is in a hill-climb travelling state.

[0017] it is mainly in the case of hill-climb travelling that an operator has a feeling of strangeness in switching between the engine output modes. It should be particularly noted in the third aspect of the present invention that it is detected whether or not the travelling state is a hill-climb travelling state. Therefore, it is possible to inhibit reduction in the vehicle speed in hill-climb travelling, and simultaneously, inhibit an operator from having a feeling of strangeness.

[0018] A wheel loader according to a fourth aspect of the present invention relates to the wheel loader according to the third aspect of the present invention. In the wheel loader, the travelling state detecting unit is configured to determine that the vehicle is in the travelling state in satisfying: a condition that a vehicle speed is less than or equal to a predetermined value; a condition that a throttle opening degree is kept to be greater than or equal to a preliminarily set threshold opening degree closer to a fully opened throttle opening degree for a predetermined period of time or greater; and a condition that a brake operation is not being performed.

[0019] It can be assumed to use a sensor for measuring inclination of the vehicle as means for detecting that the vehicle is in a hill-climb travelling state. However, cost increase is inevitable in providing the inclination sensor. Further, it is difficult fur the inclination sensor to accurately detect that the vehicle is in a hill-climb travelling state when the vehicle executes a work in a wilderness. Therefore, there are high chances of erroneous detection.

[0020] In view of the above, in the fourth aspect of the present invention, it is determined whether or not the travelling state is a hill-climb travelling state based on a general operation of an operator in hill-climb travelling. Specifically the hill-climb travelling state is established in satisfying: the condition that the vehicle speed is less than or equal to a predetermined value; the condition that the throttle opening degree is kept to be greater than or equal to a predetermined opening degree for a predetermined period of time or greater; and the condition that a brake operation is not being performed, It should be noted that continuation of a nearly fully opened throttle opening degree for a predetermined period of time or greater is set to be one of the conditions in order to exclude a state that the vehicle starts moving on a flatland.

[0021] It is herein possible to detect the hill-climb travelling state using a sensor normally provided for a wheel loader without using a special inclination sensor.

[0022] A wheel loader according to a fifth aspect of the present invention relates to the wheel loader according to the fourth aspect of the present invention. in the wheel loader, the travelling state detecting unit is further configured to determine that the vehicle is in the hill-climb travelling state when the acceleration speed is less than or equal to a predetermined value.

[0023] It is herein possible to detect that the vehicle is in the hill-climb travelling state without using a special sensor. Further, the acceleration speed is also taken into account other than the vehicle speed, the throttle opening degree and whether or not a brake operation is performed. Therefore, it is possible to reliably exclude flatland travelling with a. light toad and accurately detect the hill-climb travelling state.

[0024] A wheel loader according to a sixth aspect of the present invention relates to the wheel loader according to one of the first aspect and the third to fifth aspects of the present invention. in the wheel loader, the switching time controlling unit is configured to: determine that the vehicle has shifted from flatland travelling to hill-climb travelling and control the switching time to be the first time when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and determine that the vehicle starts moving on a hill and control the switching time to be the second time when the detected acceleration speed is positive.

[0025] Similarly to the first aspect of the present invention, the engine output modes are herein quickly switched from the low output mode to the high output mode when the vehicle has shifted from flatland travelling to hill-climb travelling. Accordingly, it is possible to inhibit a situation that the vehicle speed is reduced and acceleration per is degraded when the vehicle has shifted to hill-climb travelling. On the other hand, the switching time is increased at hill start and it is possible to avoid a situation that the work vehicle abruptly accelerates immediately after hill start. As a result, it is possible to inhibit an operator from having a feeling of strangeness.

[0026] A wheel loader according to a seventh aspect of the present invention relates to the wheel loader according to one of the second to fifth aspects of the present invention. In the wheel loader, the output torque change rate controlling unit is configured to: determine that the vehicle has shifted from flatland travelling to hill-climb travelling and control the change rate of the output torque to be the first change rate when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and determine that the vehicle starts moving on a hill and control the change rate of the output torque to be the second change rate when the detected acceleration speed is positive.

[0027] Similarly to the second aspect of the present invention, the mode switching time is herein reduced and the engine output modes are quickly changed hum the low output mode to the high output mode when the vehicle has shifted from flatland travelling to hill-climb travelling. It is thereby possible to inhibit a situation that the vehicle speed is reduced and acceleration performance is degraded when the vehicle has shifted to hill-climb travelling. On the other hand, the mode switching time is increased at hill start and it is possible to avoid a situation that the work vehicle abruptly accelerates immediately after hill start. As a result, it is possible to inhibit an operator from having a feeling of strangeness.

[0028] A wheel loader according to an eighth aspect of the present invention relates to the wheel loader according to the fifth aspect of the present invention, Lu the wheel loader, the travelling state detecting unit is further configured to detect that the vehicle is in a hill-climb released state shifted from the hill-climb travelling state as another state. Further, the mode switching determining unit is configured to switch between the engine output modes from the high output mode to the low output mode when the vehicle is detected to be in the hill-climb released state.

[0029] The hill-climb released state is herein detected and the high output mode, having been set so far, is switched into the low output mode. It is thereby possible to inhibit deterioration in fuel efficiency.

[0030] A wheel loader according to a ninth aspect of the present invention relates to the wheel loader according to the eighth aspect of the present invention. In the wheel loader, the travelling state detecting unit is configured to detect that the vehicle is in the hill-climb released state in satisfying at least one of a condition that a throttle opening degree becomes less than a threshold opening degree; and a condition that a brake operation is performed.

[0031] It is herein determined that hilt-climb travelling is finished and the high output mode becomes unnecessary either when an operator depresses an accelerator pedal and the throttle opening degree becomes less than the threshold opening degree or when a brake operation is performed. Accordingly; the high output mode is switched into the low output mode. Therefore, it is possible to avoid occurrence hunting in control.

[0032] According to the present invention as described above, a wheel loader can execute an appropriate switching control depending on a phase in switching between engine output modes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1** is an external view of a wheel loader according to an exemplary embodiment of the present invention.

[0034] FIG. **2** is a schematic block diagram of the wheel loader.

[0035] FIG. **3** includes charts representing relation between engine speed and output torque in a low output mode and that in a high output mode.

[0036] FIG. **4** is a diagram illustrating a state of flatland travelling and that of hill-climb travelling.

[0037] FIG. **5** is a flowchart for a control for switching engine output modes.

[0038] FIG. **6** represents thresholds of the vehicle speed for switching output modes.

[0039] FIG. **7** represents thresholds of the acceleration speed for switching output modes.

[0040] FIG. **8** is a chart representing variation in the acceleration speed when a vehicle shifts from flatland travelling to hill-climb travelling.

[0041] FIG. **9** is a chart representing a change rate of engine output torque with respect to the acceleration speed in switching output modes.

[0042] FIG. **10** includes charts representing variation in the vehicle speed when the vehicle has shifted from flatland travelling to hill-climb travelling.

[0043] FIG. **11** includes charts representing variation in the vehicle speed when the vehicle is started moving on a hill.

DESCRIPTION OF THE EMBODIMENTS

Structure

[0044] FIG. **1** is an external view of a wheel loader **1** as a work vehicle, while FIG. **2** is a block diagram of the schematic structure of the wheel loader **1**. The wheel loader **1** includes a vehicle body frame **2**, a work implement **3**, front wheels **4***a*, tear wheels **4***b* and a cab **5**. The wheel loader **1** can be self-propelled by driving and rotating the front wheels **4***a* and the rear wheels **4***b*. The wheel loader **1** can execute a desired work using the work implement **3**.

[0045] The vehicle body frame **2** includes a front vehicle body part **2***a* and a rear vehicle body part **2***b*. The front vehicle body part **2***a* and the rear vehicle body part **2***b* are coupled while being pivotable in a right-and-left direction. The front vehicle body part **2***a* is provided with the work implement **3** and the front wheels **4***a*. The rear vehicle body part **2***b* is provided with the cab **5** and the rear wheels **4***b*. The work implement **3** includes a boom **6**, a bucket **7**, a bell crank **8** and etc. The boom **6** is configured to be pivoted up and down by means of a pair of lift cylinders **10**. Further, the bucket **7** is attached to the tip of the boom **6**. The bucket **7** is configured to be pivoted up and down by means of a bucket cylinder **11** through the bell crank **8**.

[0046] As illustrated in FIG. **2**, the wheel loader **1** further includes an engine **15**, a power take-off (PTO) **16**, a power transmission mechanism **17**, a cylinder driving unit **18** and a control unit **19**.

[0047] The output of the engine **15** is controlled by regulating the amount of fuel to be injected into a cylinder The amount of fuel is regulated through the control of an electric governor **21** attached to a fuel injection pump **20** of the engine **15** by the control unit **19**.

[0048] The power take-off **16** is a device configured to divide and distribute the output of the engine **15** to the power transmission mechanism **17** and the cylinder driving unit **18**.

[0049] The power transmission mechanism **17** is a device configured to transmit the driving force from the engine **15** to the front wheels **4***a* and the rear wheels **4***b*. The power transmission mechanism **17** includes a torque converter **22** and a transmission **23**. The transmission **23** includes a toward/rearward travel clutch and a plurality of speed stage clutches corresponding to a plurality of speed stages. In the present exemplary embodiment, the transmission **23** is provided with four speed stage clutches and the speed stages can be switched among four stages from a first speed to a fourth speed.

[0050] The cylinder driving unit **18** includes a hydraulic pump **25** and a control valve **26**. The output of the engine **15** is transmitted to the hydraulic pump **25** through the power take-off **16**. Further, the operating oil discharged from the hydraulic pump **25** is supplied to the lift cylinders **10** and the bucket cylinder **11** through the control valve **26**, It should be noted that the front wheels **4***a* and the rear wheels **4***b* are provided with wet multiple-disc hydraulic brake devices although not illustrated in FIGS. **1** and **2**.

[0051] The control unit **19** is formed by a microcomputer including a RAM, a ROM, a CPU and etc. Signals are inputted into the control unit **19** from the following sensors.

[0052] (1) An accelerator opening degree sensor **29** configured to detect the opening angle of an accelerator pedal **28**.

[0053] (2) A brake operation sensor **31** configured to detect an operation of a brake pedal **30**.

[0054] (3) An output shaft rotation speed sensor **32** of the transmission **23**. The control unit **19** is configured to calculate the vehicle speed and the acceleration speed based on a detection signal from the output shaft rotation speed sensor **32**. Therefore, the output shaft rotation speed sensor **32** functions as a vehicle speed sensor and an acceleration speed sensor.

[0055] (4) A bottom pressure sensor **33** of the lift cylinders **10**.

[0056] (5) A position sensor **35** of a forward/rearward travel lever **34**.

[0057] (6) A position sensor **37** of a gear-shift lever **36**.

[0058] Based on signals from the aforementioned sensors, the control unit **19** is configured to control the engine **15** and execute a variety of controls such as a driving control of the work implement driving unit **18**, a gear-shift control of the transmission **23** and a brake control of the brake devices (not illustrated in the figures), It is notable that the control unit **19** has a travelling state detecting function, a mode switching determining function, an acceleration speed detecting function and a switching time controlling function, regarding a control of the output modes of the engine **15**. The travelling state detecting function is a function of detecting whether or not the wheel loader **1** is in a hill-climb travelling state. The mode switching determining function is a function of determining that it should be currently required to switch between engine output modes from a low output mode to a high output mode when it is determined that the wheel loader **1** is in the hill-climb travelling state. The acceleration speed detecting function is a function of detecting the acceleration speed of the wheel loader **1** when it is determined that the engine output modes should be switched from the low output mode to the high output mode. The switching time controlling function is a function of controlling a switching time from the start to the end of mode switching in accordance with the acceleration speed.

Engine Output Modes

[0059] The control unit **19** is configured to execute a control of switching between the output modes of the engine **15** from a low output mode to a high output mode or vice versa. FIG. **3** represents curves of torque that can be outputted by the engine **15** in accordance with the rotation speed in the respective modes. The low output mode depicted with a solid line in FIG. **3**(*a*) is a mode for achieving low fuel consumption. In the low output mode, the output torque is inhibited excluding in the low engine speed range and the high engine speed range. The low output mode is selected under a light load condition such as flatland travelling as illustrated in FIG. **4**(*a*) and when the vehicle starts moving. The high output mode depicted with a solid line in FIG. **3**(*b*) is a mode whereby higher output torque can be obtained than the low output mode. The high output mode is selected in hill-climb travelling as illustrated in FIG. **4**(*b*).

[0060] Further, the control unit **19** is configured to execute a switching control of the output mode of the engine **15** between a power mode and an economy mode in response to an operator's instruction. The power mode is a mode to be selected by an operator when large engine output is required in either travelling or working. On the other hand, the economy mode is a mode for inhibiting the engine output at a lower level to achieve low fuel consumption.

[0061] It should be noted that the aforementioned output control of the engine **15** is executed by, for instance, controlling the upper limit of the amount of fuel to be injected into the engine **15**.

Output Mode Switching Control

[0062] As described above, the present wheel loader **1** has the low output mode and the high output mode as the engine output modes. Further, the low output mode is selected for achieving low fuel. consumption under a. light load condition such as flatland travelling. On the other hand, the high output mode is selected under a heavy load condition such as hill-climb travelling. The output mode switching control will be hereinafter explained using a flowchart represented in FIG. **5**.

[0063] In Step S**1**, it is determined whether or not the vehicle is in a hill-climb travelling state. It is herein determined that the vehicle is in the hill-climb travelling state when the following conditions **1** to **4** are all satisfied.

[0064] Condition **1**: either a fully-accelerated state (an acceleration opening degree of 100%) or a state that an acceleration opening degree is greater than a predetermined value and this is maintained for a predetermined period of time or greater.

[0065] Condition **2**: a brake operation is not being performed. Specifically, the brake pedal **30** is not being pressed down.

[0066] Condition **3**: the vehicle speed and the acceleration speed are respectively less than or equal to values represented in FIGS. **6** and **7**. A threshold value is herein set for each of the vehicle speed and the acceleration speed depending on which of the gear stages is being selected. It should be noted that these values can be changed depending on the mode (the power mode, the economy mode, etc.) or the loading condition (empty or loaded).

[0067] Condition **4**: the vehicle is not in a digging state. Specifically, the bottom pressure of the lift cylinders **10** is less than or equal to a predetermined value and this is maintained for a predetermined period of time or greater.

[0068] The processing proceeds from Step S**1** to Step S**1** unless the aforementioned conditions **1** to **4** are all satisfied. In Step S**2**, the low output mode is maintained as an engine output mode.

[0069] On the other hand, the processing proceeds from Step S**1** to Step S**3** when the conditions **1** to **4** are all satisfied. In Step S**3**, calculation is performed for the acceleration speed at a point of time when the conditions **1** to **4** are all satisfied. It may be herein possible to use an average of the acceleration speed from the point of time when the conditions **1** to **4** are all satisfied to another point of time earlier than the point of time by a predetermined period of time.

[0070] Next in Step S**4**, it is determined whether or not the acceleration speed is either **0** or negative. When the acceleration speed average (or the acceleration speed) calculated in Step S**3** is either 0 or negative, it is determined that the wheel loader **1** has shifted from flatland travelling to hill-climb travelling. Accordingly, the processing proceeds from Step S**4** to Step S**5**. In Step S**5**, the engine output modes are switched from the low output mode to the high output mode in a short switching time. This will be hereinafter explained in detail.

[0071] First, light load is applied in flatland travelling, and therefore, the low output mode is set as an engine output mode. When the vehicle then shifts from a flatland illustrated in FIG. **4**(*a*) to an uphill illustrated in FIG: **4**(*b*), the vehicle speed is gradually reduced. FIG. **8** represents variation in the acceleration speed with time under the condition. As represented in FIG. **8**, when the vehicle shifts from flatland travelling to hill-climb travelling, the acceleration speed is reduced with time and becomes negative. When the aforementioned conditions I to **4** are all satisfied, it is determined that the vehicle has shifted to hill-climb travelling.

[0072] Next, when the vehicle has shifted from flatland travelling to hill-climb travelling, i.e., when the acceleration speed is either 0 or negative, the low output mode is quickly switched into the high output mode. Specifically, the acceleration is negative as represented in FIG. **8**, and therefore, the low output mode is switched into the high output mode in a short switching time by setting a change rate of the engine output torque, i.e., T/n (T: Nm, n: 0.01 sec) to be "T_1".

[0073] FIG. **10** represents difference of reduction in the vehicle speed between different switching time settings when the vehicle has shifted from flatland travelling to hill-climb travelling. FIG. **10**(*a*) represents a case that the switching time of the output mode from a switching start clock time Ts to a switching end clock time Te is set to be relatively long by reducing the change rate T/n of the engine output torque to be T_2 ($<T_1$). On the other hand, FIG. **10**(*b*) represents a case that the switching time from the switching start clock time Ts to the switching end clock time Te is set to be relatively short by increasing the change rate T/n of the engine output torque. As is obvious from the figures, it is possible to reduce decline in the vehicle speed by shortening the switching time.

[0074] On the other hand, when the acceleration speed (or the acceleration speed average) calculated in Step S**3** is positive, it is determined that the vehicle starts moving on a hill. Accordingly; the processing proceeds from Step S**4** to Step S**6**. In Step S**6**, the engine output modes are switched from the low output mode to the high output mode in a long switching time. This will be hereinafter explained in detail.

[0075] First, the low output mode is set as an engine output mode when the vehicle starts moving. Therefore, the low output mode is selected as an engine output mode even at hill start. Further, at hill start, the vehicle speed is gradually increased with time even in the low output mode. Therefore, the acceleration speed becomes positive. When it is thus determined that the vehicle is in the hill-climb travelling state while the acceleration speed is positive, the low engine output mode is gently switched into the high output mode. Specifically as represented in FIG. **9**, the change rate of the engine output torque, i.e., T/n is set to be a value falling in a range from "T_1" to "T_2($<T_1$)" in accordance with the acceleration speed.

[0076] FIG. **11** represents variation in the vehicle speed at hill start. An example represented in FIG. **11**(*a*) relates to a case that the switching time from the switching start clock time Ts to the switching end clock time Te is set to be relatively long similarly to the present exemplary embodiment by setting the change rate of the engine output torque to be T_2. In this case, the vehicle speed is gradually increased, and therefore, an operator does not have a feeling of strangeness. On the other hand, an example represented in FIG. **11**(*b*) relates to a case that the switching time is set to be shorter than that in FIG. **11**(*a*) by setting the change rate of the engine output torque to be T_1. In this case, the vehicle speed is increased in a short time immediately after the output mode is started being switched into the high output mode. Therefore, an operator has a feeling of strangeness.

[0077] As described above, when it is determined that the vehicle is in hill-climb travelling, the change rate of the output torque in switching the low output mode into the high output mode is changed in accordance with the acceleration speed. Therefore, the low output mode is quickly switched into the high output mode when the vehicle has shifted from flatland travelling to hill-climb travelling. Accordingly, decline in the vehicle speed can be reduced. At hill start, on the other hand, the low output mode is gently switched into the high output mode. Therefore, abrupt increase in the vehicle speed can be inhibited and thereby an operator can be inhibited from having a feeling of strangeness.

[0078] Next in Step **S7**, it is determined whether or not a hill-climb released condition is established. In other words, the processing proceeds from Step **S7** to Step **S2** either when the acceleration opening degree is reduced and thereby the condition I. is not satisfied or when a brake operation is performed and thereby the condition **2** is not satisfied. Accordingly, the engine output modes are switched from the high output mode to the low output mode.

Advantageous Effects of Exemplary Embodiment

[0079] (1) The time of switching between the engine output modes is controlled by detecting the hill-climb travelling state and simultaneously controlling the change rate of the engine output torque in accordance with the acceleration speed at that time. Therefore, it is possible to execute an appropriate switching control depending on a travelling phase.

[0080] Specifically, when the vehicle has shifted from flatland travelling to hill-climb travelling, the engine output modes are quickly switched from the low output mode to the high output mode. Therefore, it is possible to inhibit reduction in the vehicle speed and degradation in the acceleration performance immediately after the vehicle shifted to hill-climb travelling. Further, at hill start, the low output mode is gently switched into the high output mode. Therefore, the vehicle can be avoided from abruptly accelerating at hill start. This makes an operator less feel strange.

[0081] (2) it is detected that the vehicle is in a hill-climb travelling state using a sensor normally embedded in a wheel loader. Therefore, it is not required to provide a special sensor such as an inclination sensor. Further, error detection can be avoided.

[0082] (3) it is detected that the vehicle is not in a hill-climb travelling state based on either the fact that the throttle opening degree becomes less than a threshold or the fact that a brake operation is performed. Therefore, it is possible to avoid occurrence of hunting in control.

OTHER EXEMPLARY EMBODIMENTS

[0083] The present invention is not limited to the aforementioned exemplary embodiment and a. variety of changes or modifications can be herein made without departing from the scope of the present invention.

[0084] Numeric values described in the aforementioned exemplary embodiment are exemplary only, and the present invention is not limited to the numeric values.

[0085] According to the aforementioned wheel loader, an appropriate switching control can be performed depending on a phase in switching between engine output modes.

1. A wheel loader having a low output mode and a high output mode as engine output modes, the wheel loader comprising:
- an engine;
- a driving wheel;
- a power transmission device configured to transmit driving force from the engine to the driving wheel;
- a work implement configured to be driven by the driving force from the engine; and
- an engine control device configured to execute a control of switching between the engine output modes from the low output mode to the high output mode or vice versa, wherein the engine control device includes:
  - a travelling state detecting unit configured to detect a travelling state of the wheel loader;
  - a mode switching determining unit configured to determine based on a detection result by the travelling state detecting unit whether or not it is required to switch between the engine output modes from the low output mode to the high output mode;
  - an acceleration speed detecting unit configured to detect an acceleration speed of the wheel loader when the mode switching determining unit determines that it is required to switch between the engine output modes; and
  - a switching time controlling unit configured to control a switching time from start to end of the mode switching to be: a first time when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and a second time greater than the first time when the detected acceleration speed is positive.

2. A wheel loader having a low output mode and a high output mode as engine output modes, the wheel loader comprising:
- an engine;
- a driving wheel;
- a power transmission device configured to transmit driving force from the engine to the driving wheel;
- a work implement configured to be driven by the driving force from the engine; and
- an engine control device configured to execute a control of switching between the engine output modes from the low output mode to the high output mode or vice versa,
- wherein the engine control device includes:
  - a travelling state detecting unit configured to detect a travelling state of the wheel loader;
  - a mode switching determining unit configured to determine based on a detection result by the travelling state detecting unit whether or not it is required to switch between the engine output modes from the low output mode to the high output mode;
- an acceleration speed detecting unit configured to detect an acceleration speed of the wheel loader when the mode switching determining unit determines that it is required to switch between the engine output modes; and
- an output torque change rate controlling unit configured to control a change rate of an output torque of the engine from start to end of the mode switching to be: a first change rate when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and a second change rate less than the first change rate when the detected acceleration speed is positive.

3. The wheel loader recited in claim **1**, wherein
- the travelling state detecting unit is configured to detect that the wheel loader is in a hill-climb travelling state.

4. The wheel loader recited in claim **3**, wherein
- the travelling state detecting unit is configured to determine that the wheel loader is in the hill-climb travelling state in satisfying: a condition that a vehicle speed is less than or equal to a predetermined value; a condition that a throttle opening degree is kept to be greater than or equal to a preliminarily set threshold opening degree closer to a fully opened throttle opening degree for a predetermined period of time or greater; and a condition that a brake operation is not being performed.

5. The wheel loader recited in claim **4**, wherein
- the travelling state detecting unit is further configured to determine that the wheel loader is in the hill-climb trav-

elling state when the acceleration speed is less than or equal to a predetermined value.

6. The wheel loader recited in claim **1**, wherein

the switching time controlling unit is configured to: determine that the wheel loader has shifted from flatland travelling to hill-climb travelling and control the switching time to be the first time when the acceleration speed detected by the acceleration speed detecting unit is either 0 or negative; and determine that the wheel loader starts moving on a hill and control the switching time to be the second time when the detected acceleration speed is positive.

7. The wheel loader recited in claim **2**, wherein

the output torque change rate controlling unit is configured to: determine that the wheel loader has shifted from flatland travelling to hill-climb travelling and control the change rate of the output torque to be the first change rate when the acceleration speed detected by the acceleration speed detecting unit is either **0** or negative; and determine that the wheel loader starts moving on a hill and control the change rate of the output torque to be the second change rate when the detected acceleration speed is positive.

8. The wheel loader recited in claim **5**, wherein

the travelling state detecting unit is further configured to detect that the wheel loader is in a hilt-climb released state shifted from the hill-climb travelling state as another state, and

the mode switching determining unit is configured to switch between the engine output modes from the high output mode to the low output mode when the wheel loader is detected to be in the hill-climb released state.

9. The wheel loader recited in claim **8**, wherein

the travelling state detecting unit is configured to detect that the wheel loader is in the hill-climb released state in satisfying at least one of: a condition that a throttle opening degree becomes less than the threshold opening degree; and a condition that a brake operation is performed.

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